Investigation of Coherent Diffraction Radiation from a dual target system at CTF3

Konstantin Lekomtsev, Grahame Blair, Gary Boorman, Pavel Karataev
John Adams Institute at Royal Holloway University of London

Roberto Corsini, Thibaut Lefevre
CERN

K.V.Lekomtsev@rhul.ac.uk

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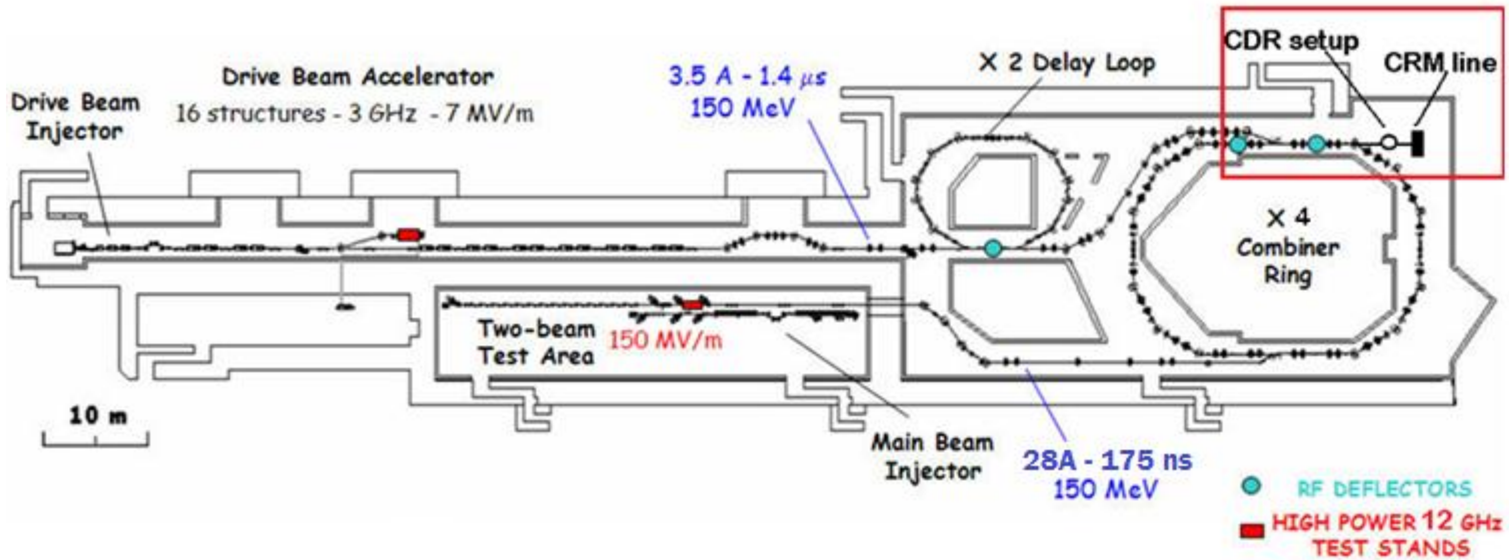
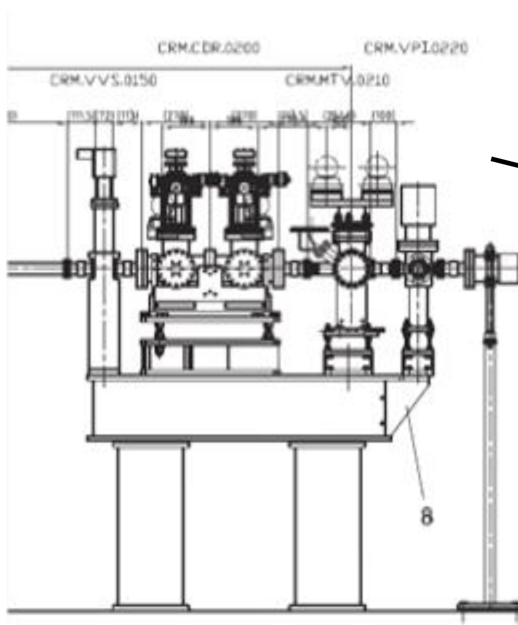
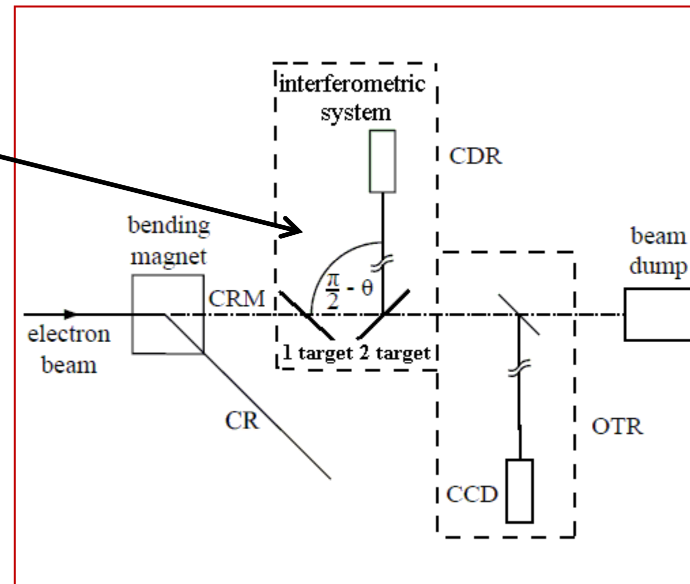
CLIC Test Facility 3 and CDR experiment

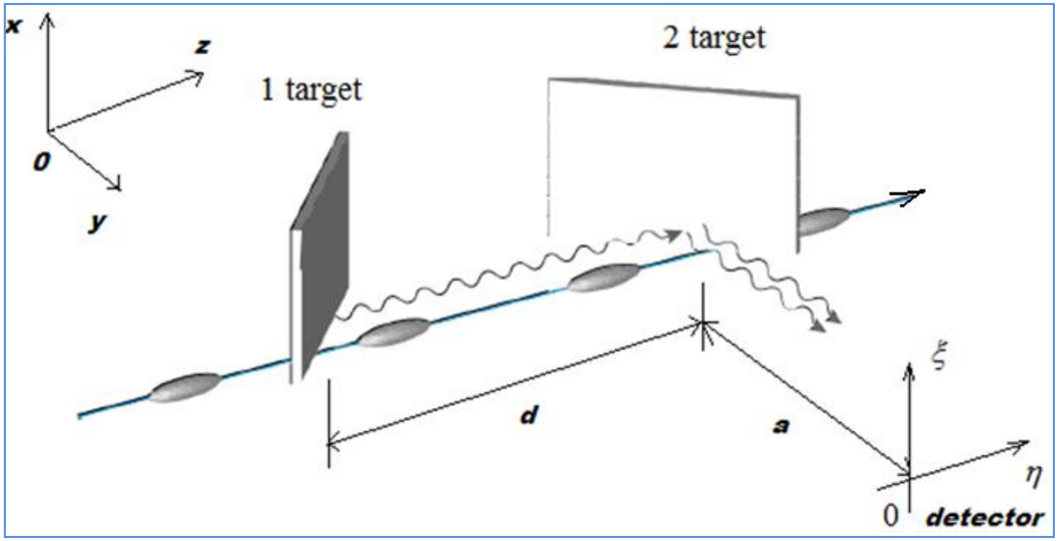


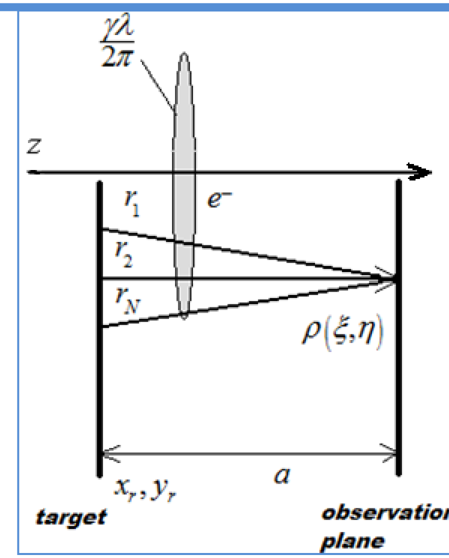
During the experiment running the electron beam had a train length of 200 to 300 ns, a bunch sequence frequency of 3GHz and a nominal current of 3.75 A.





Two target configuration

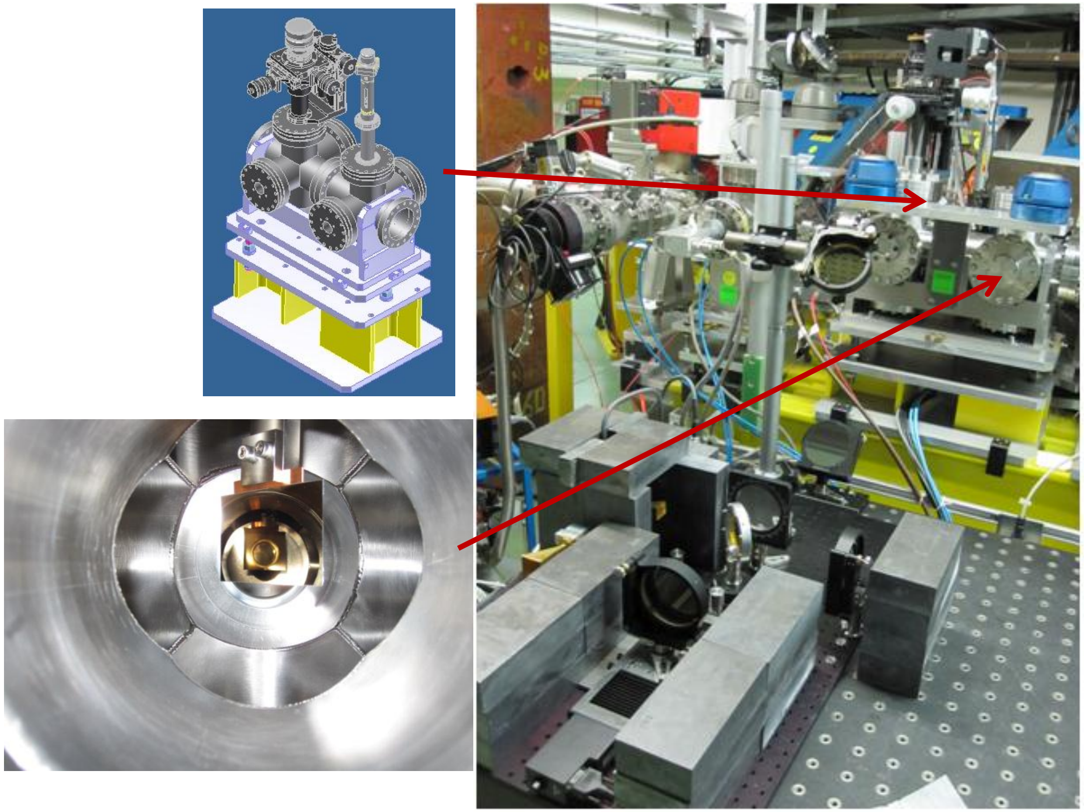


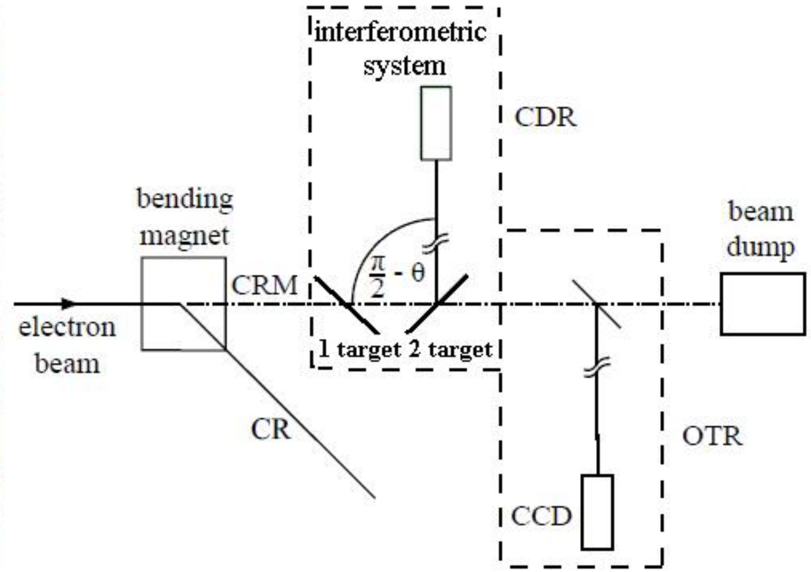


- CSR background suppression by the first target.
- Low cost and complexity of the configuration.
- Possibility of multiple reflection suppression, by installing an absorber in the upstream cross.

Beam energy (γ)	235	
Bunch charge	2.3	nC
Bunch spacing frequency	1.5 or 3	GHz
Target dimensions (projected)	40x40	mm
Observation wavelength	5	mm
First target impact parameter (upper pos.)	30	mm
First target impact parameter (lower pos.)	10	mm
Second target impact parameter	10	mm
Distance between the targets	0.25	m
Distance from the second target to the observ. plane	2	m

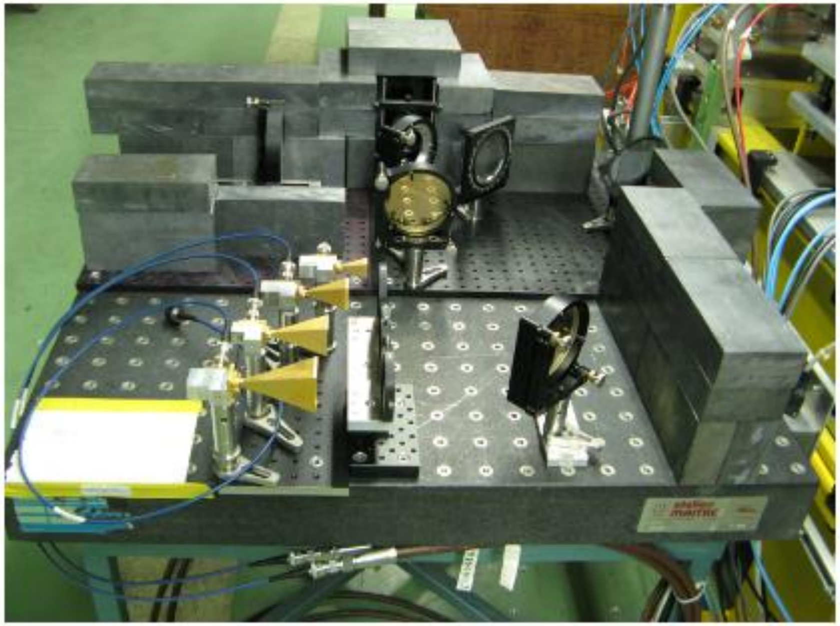
Experimental setup at CTF3

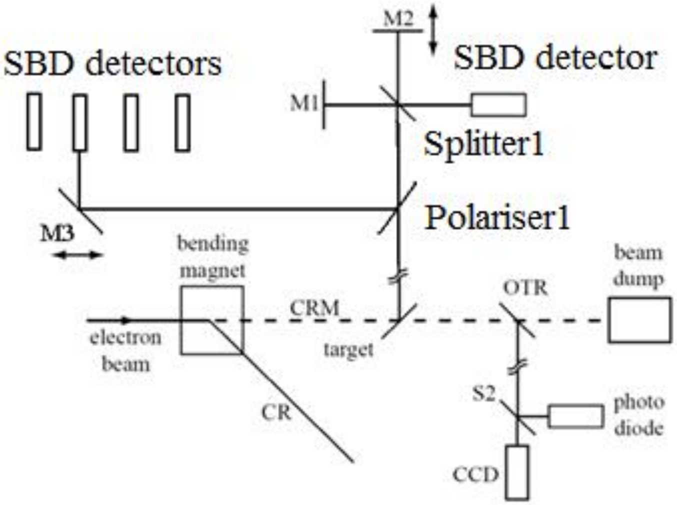


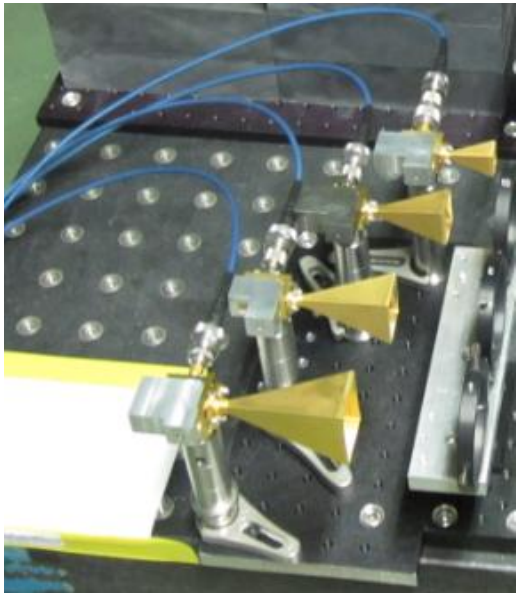


- Two UHV six-way crosses contain aluminium coated silicon targets (60mmx40mm) to one side of the beam.
- The targets are attached to the UHV manipulators, which provide precise control of the rotational and the vertical translation axes for the downstream target and a vertical translation axis for the upstream target.
- The radiation originated from the targets is translated vertically by the periscope towards the interferometer.

Interferometric system







Model Number	DXP-19	DXP-15	DXP-12	DXP-08
Frequency band and range (GHz)	U 40-60	V 50-75	E 60-90	F 90-140
Video voltage (mV at -20 dB input) (typ)	18	15	13	10
Video sensitivity (mV/mW) (min into 1 MΩ)	1000	850	700	300
Flatness (dB) (typ)	±1.5	±1.5	±2.0	±3.0
TSS at 1 kHz (bw 40 Hz, dBm) (typ)[*1]	-50	-50	-45	-40
Video bandwidth (MHz) (typ)[*2]	10	10	10	10
Operating RF input power (dBm, CW max)	+16	+16	+16	+16
Absolute max rating (dBm)	+20	+20	+20	+20

Spectral measurements

$$S_{coh}(\omega) = N^2 S_e(\omega) F(\omega)$$

$S_{coh}(\omega)$ -coherent radiation spectrum (derived from the interferometric measurements by applying Fourier transformation)

N - number of electrons in the bunch (derived from the current readout)

$S_e(\omega)$ - single electron spectrum (can be obtained by integrating the CDR distribution over the detector aperture)

$F(\omega)$ -longitudinal bunch form factor (the ultimate goal of the measurements, form factor is used for minimal phase and bunch charge distribution reconstruction)

Theoretical studies for the two target system.

Two polarisation components of the DR from the two targets:

$$E_{\xi,\eta} = \frac{ik}{8\pi^3} \iint\limits_{r_1,r_2} E_1(r_1) \frac{\exp[i(\varphi_1+\varphi_2)]}{ad} dr_1 dr_2 + \frac{1}{4\pi^2} \int\limits_{r_2} E_2(r_2) \frac{\exp[i\varphi_2 + ikd/\beta]}{a} dr_2.$$

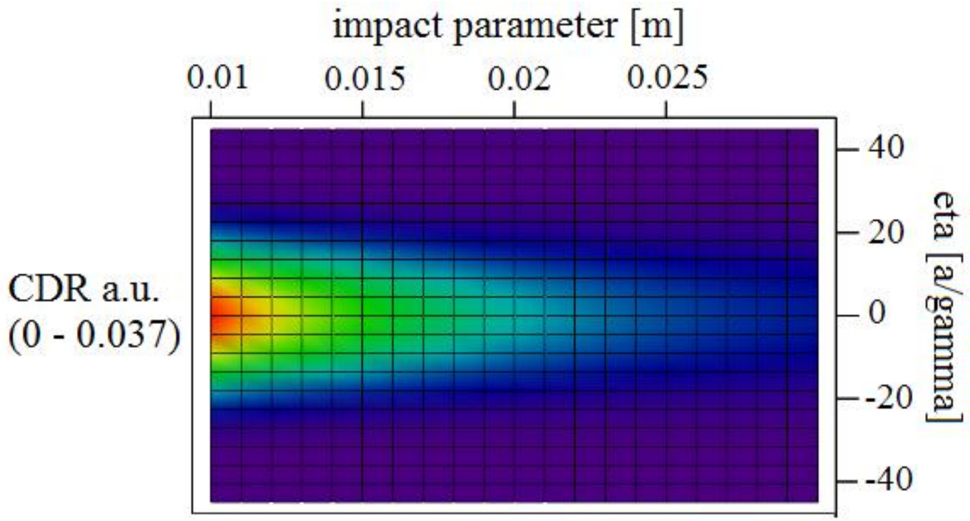
r_1 and r_2 are the coordinates of the particle field at the first and at the second target; E_1 and E_2 are the amplitudes of arbitrary elementary radiation sources on the first and the second target ; φ_1 is the phase advance of the photons propagating from the first target to the second one; φ_2 is the phase advance of the photons propagating from the second target to the observation plane; a is the distance from the second target to the observation plane; d is the distance between the targets.

The DR distribution at the observation plane can be calculated using the following formula:

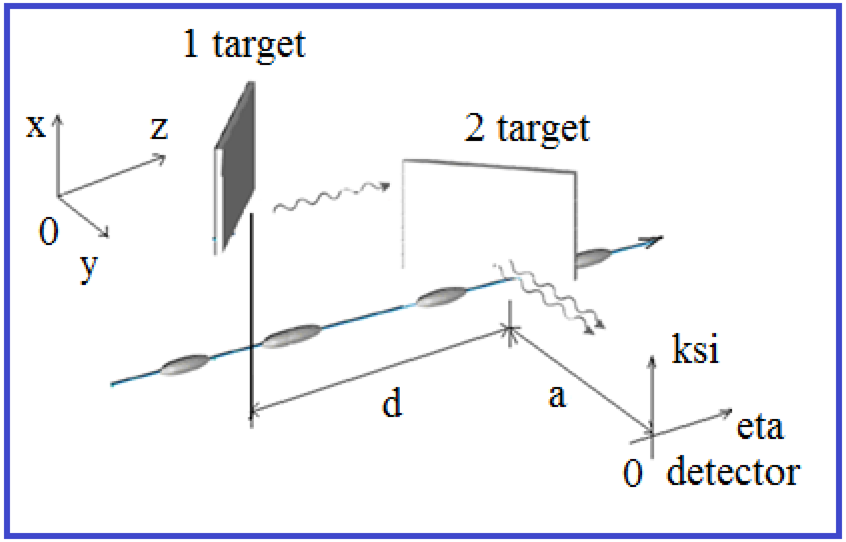
$$\frac{d^2W^{DR}}{d\omega d\Omega} = 4\pi^2k^2a^2\left[\left|E_\xi^{DR}\right|^2 + \left|E_\eta^{DR}\right|^2\right]$$

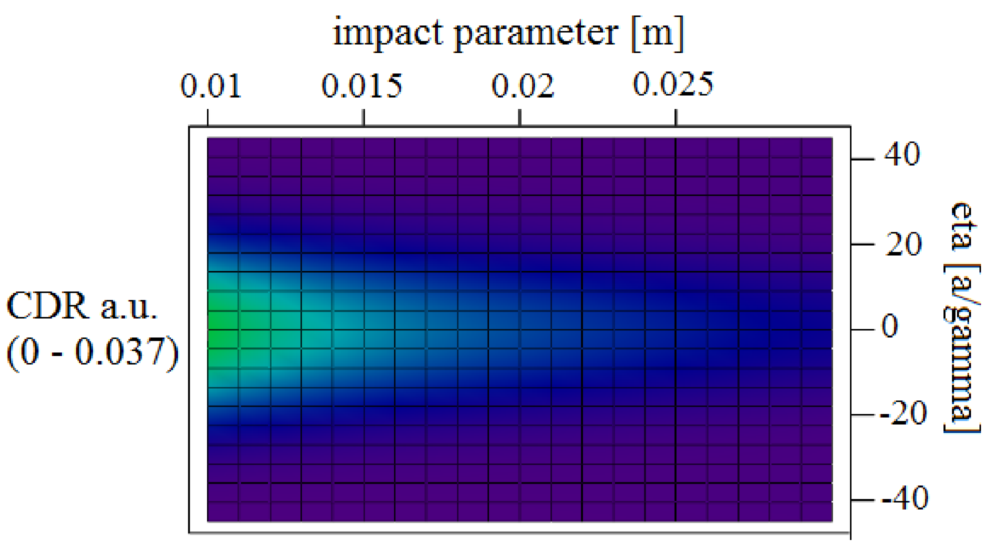
*K. Lekomtsev, G. Blair, G. Boorman, R. Corsini, P. Karataev, T. Lefevre and M. Micheler, Coherent Diffraction Radiation experiment at CTF3 – simulation studies, IL NUOVO CIMENTO Vol. 34C, N.4, 2010 (available online).

Vertical polarisation of the CDR distribution: theory

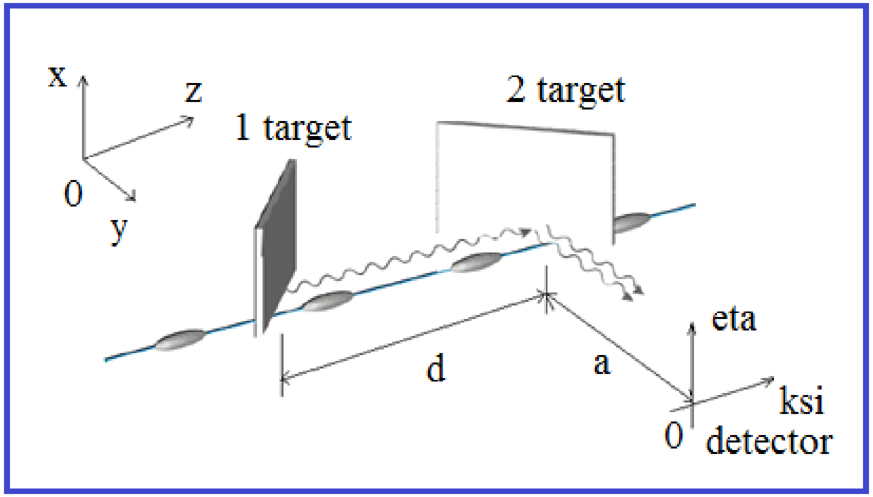


h1=30 mm; h2=10mm

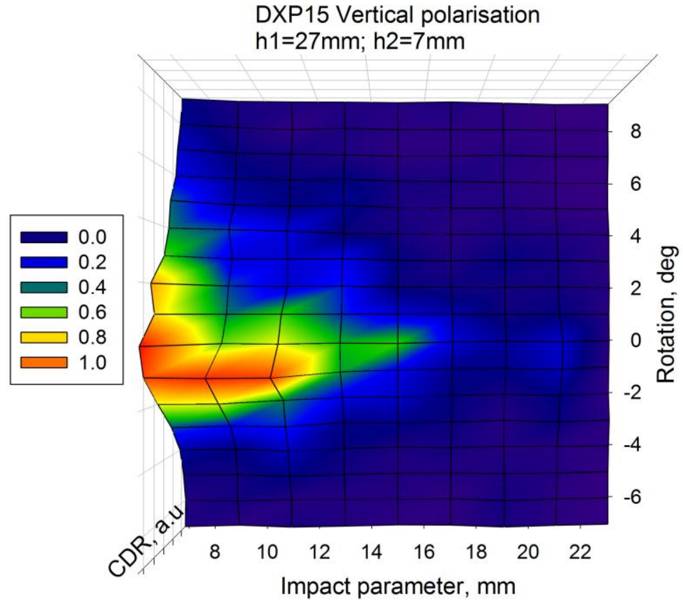


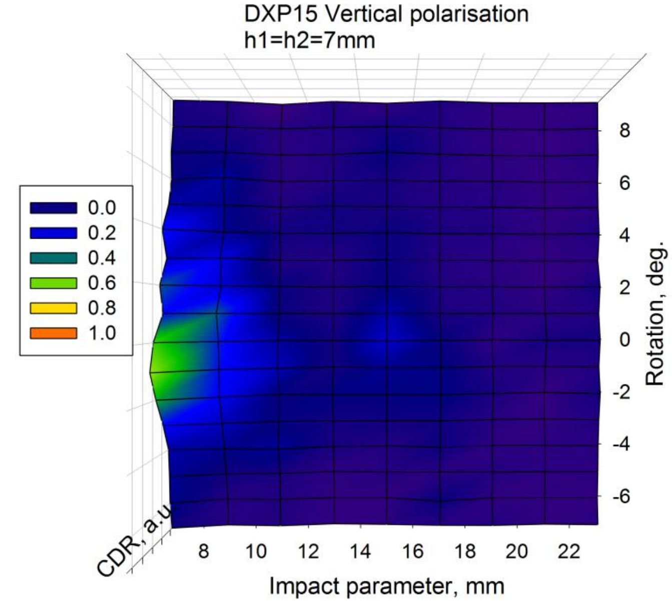


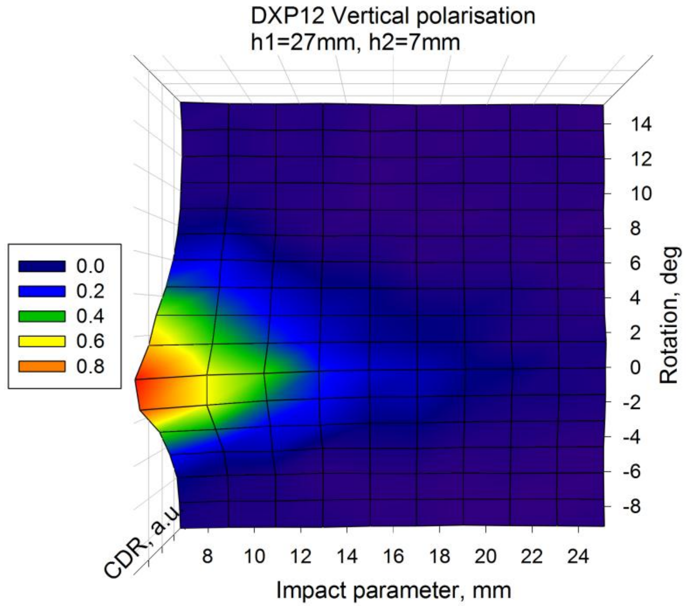
h1 = h2 = 10mm

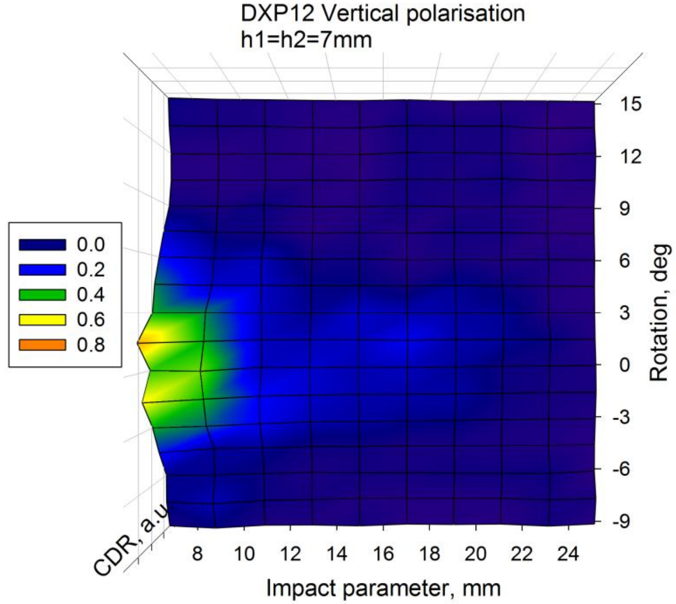


Vertical polarisation of the CDR distribution: experiment



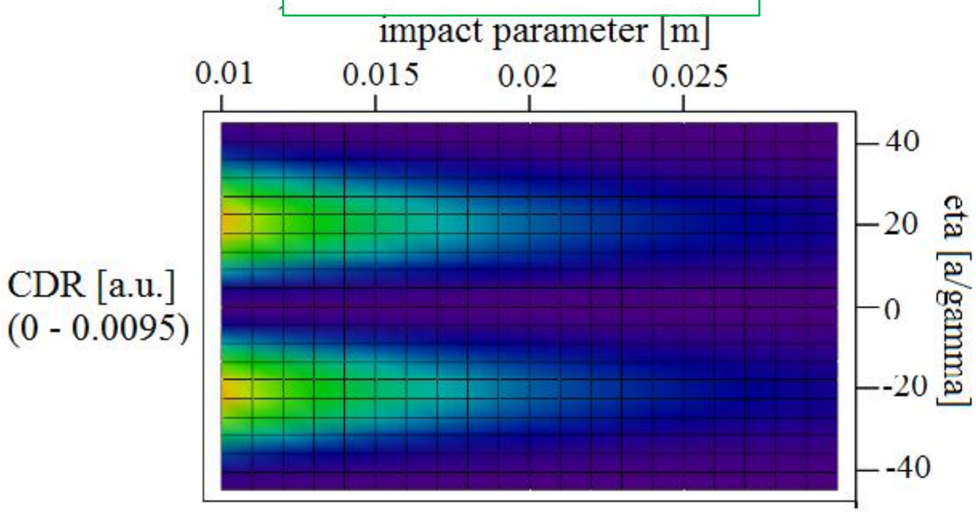


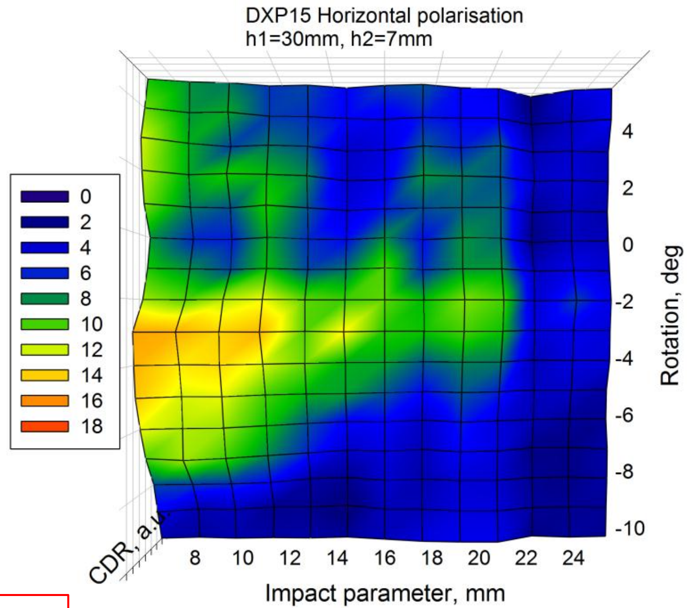




Horizontal polarisation of the CDR distribution: theory and experiment

h1=30 mm; h2=10mm

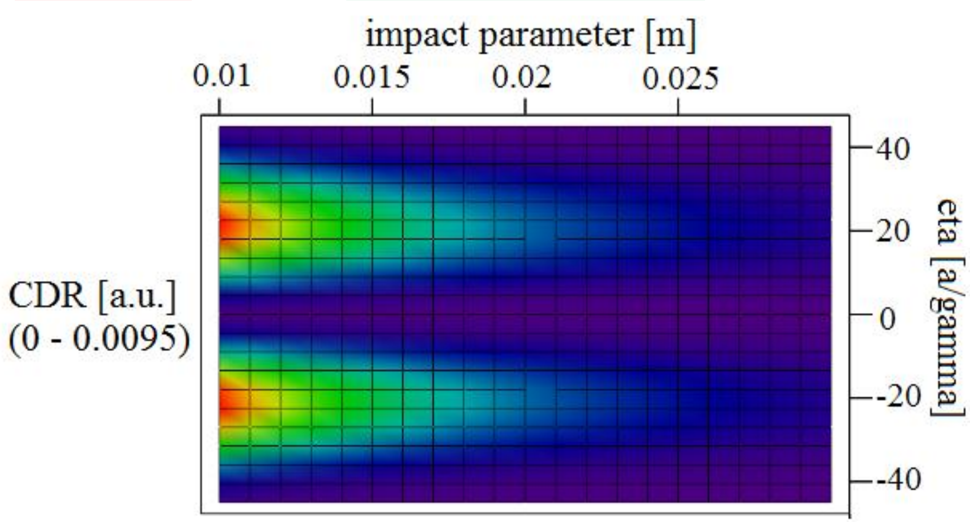


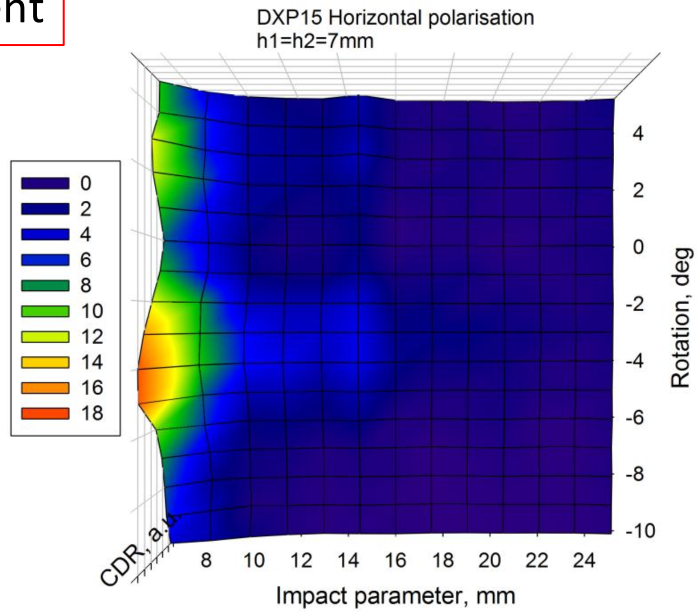


Theory

h1 = h2 = 10mm

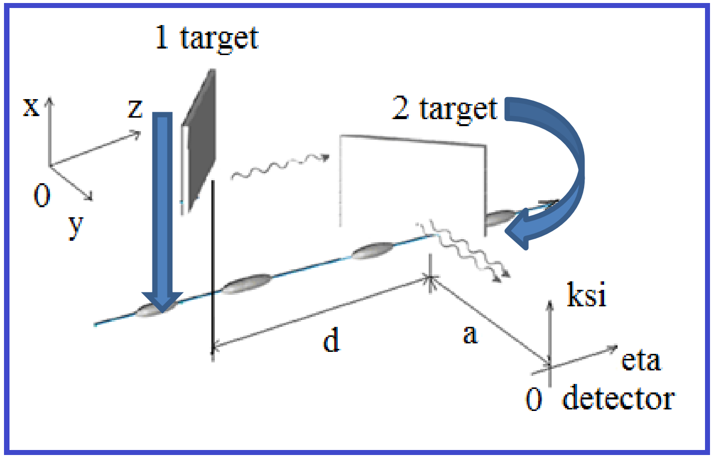
Experiment

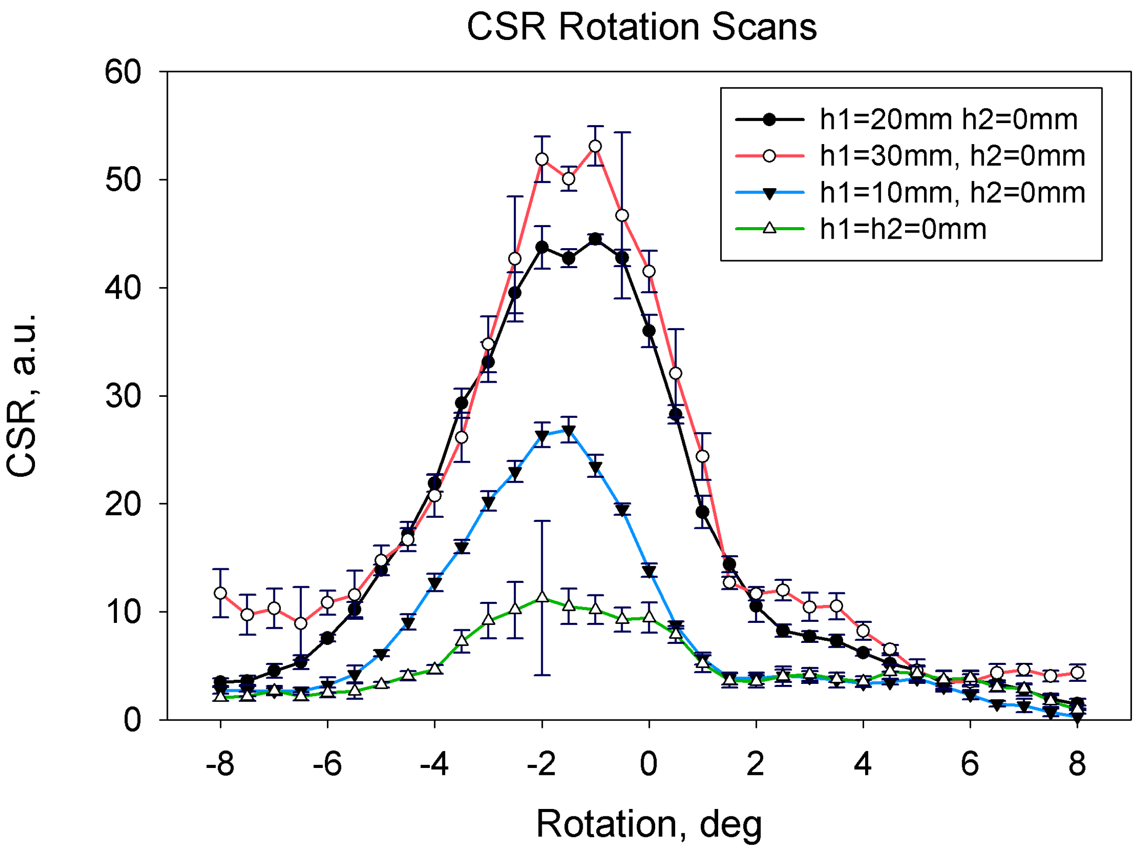




CSR background contribution studies

Reflection of the CSR from the target is investigated. The rotation scans of the horizontal polarisation component of the CSR are presented. The scans are taken for four fixed positions of the first (upstream) target, while the second target is rotated and positioned in the centre of the downstream six way cross.

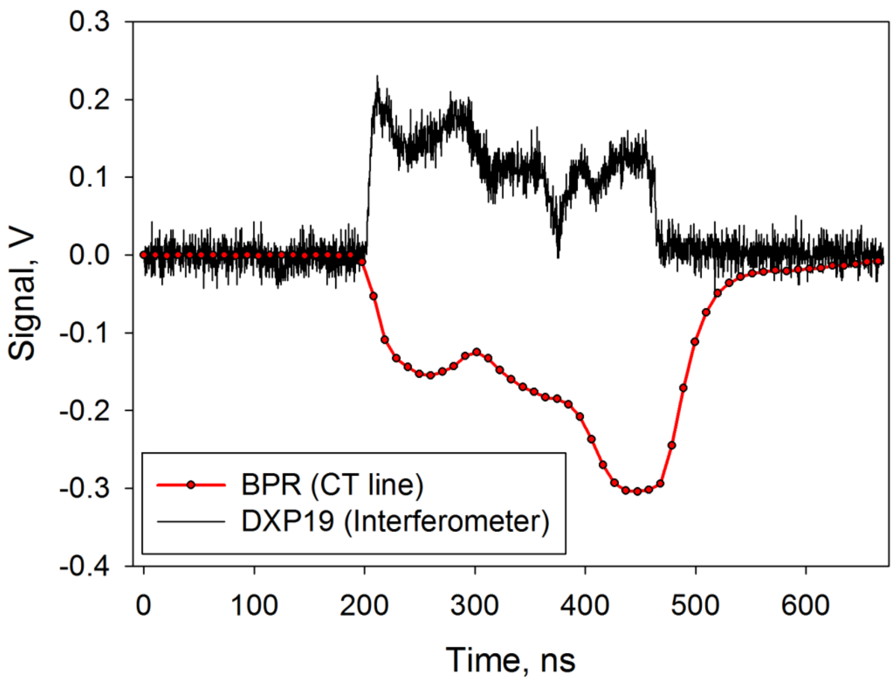


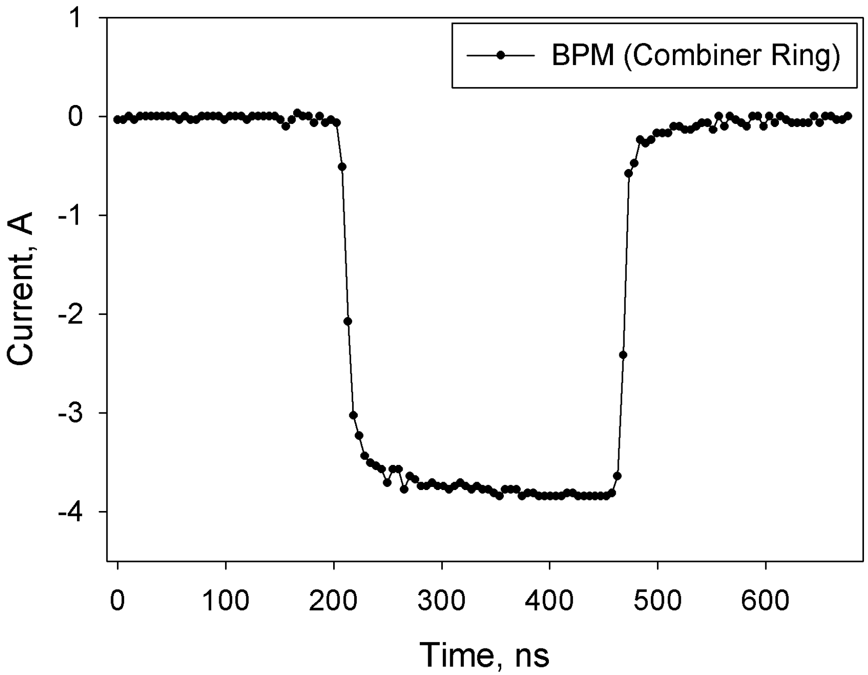


Bunch length/shape stability

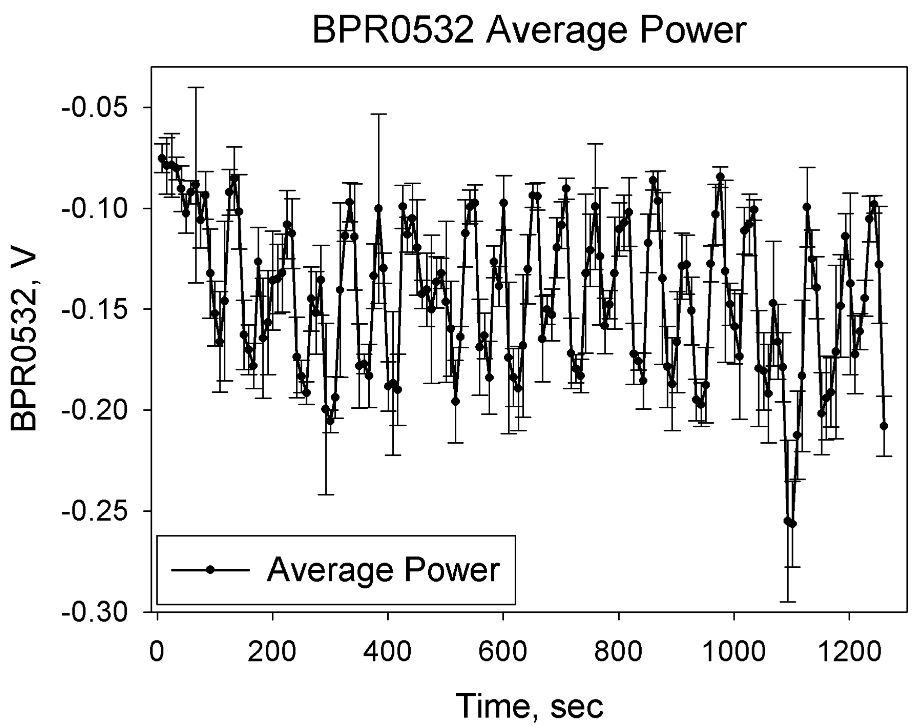
Red curve: the signal from the waveguide pickup positioned upstream of the experimental setup, the power is detected by an SBD detector sensitive in 26.5 – 40 GHz.
Black curve: the signal from DXP19 detector in the interferometer, according to specification sensitive in 40 – 60 GHz.

The signal from the last BPM before the experimental setup in the CRM line.

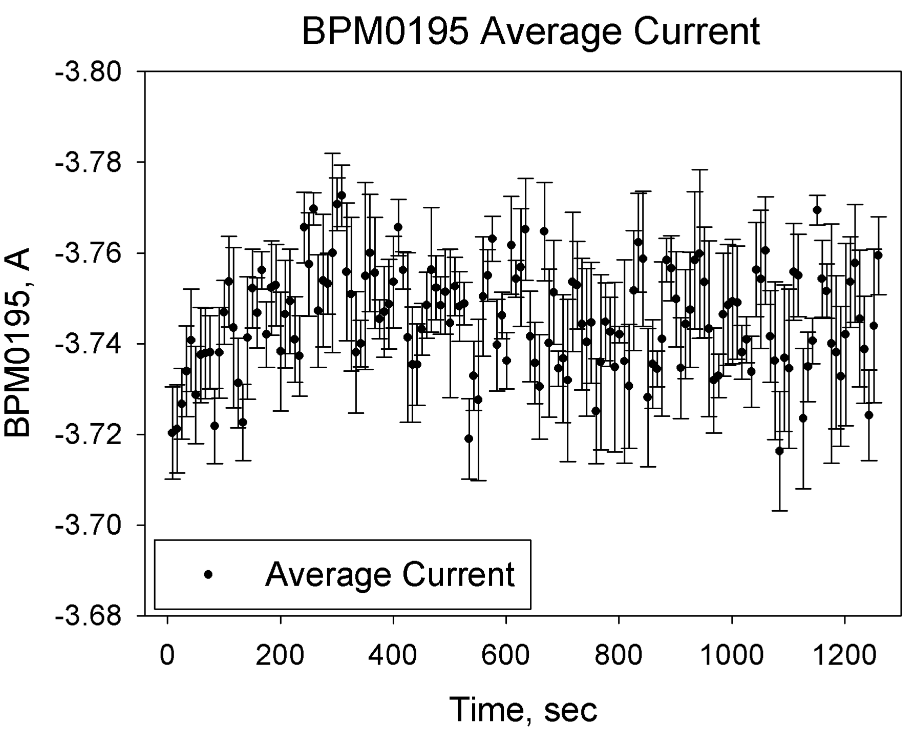




Bunch length/shape stability

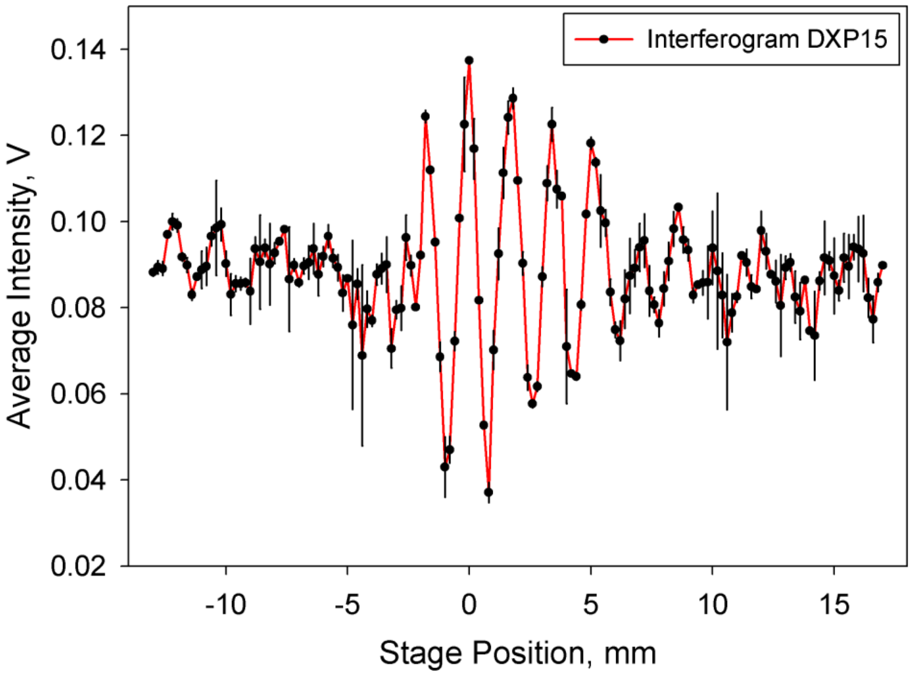


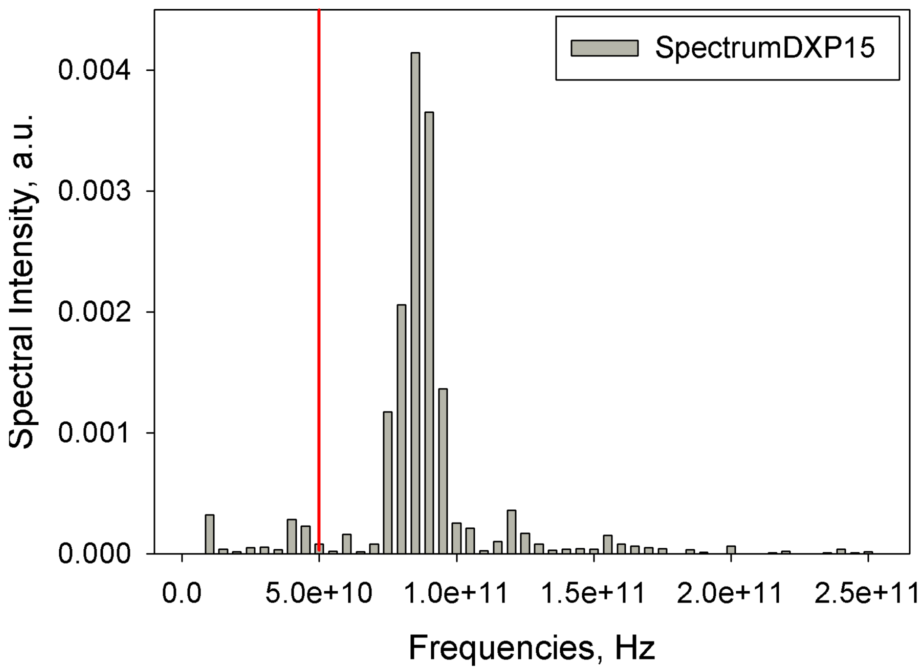
Average power scan over 21 minutes. Represents peculiar behaviour of the machine at the measurement time and significant bunch length/shape variation along the pulse. The average power with approximately factor 2 variation.

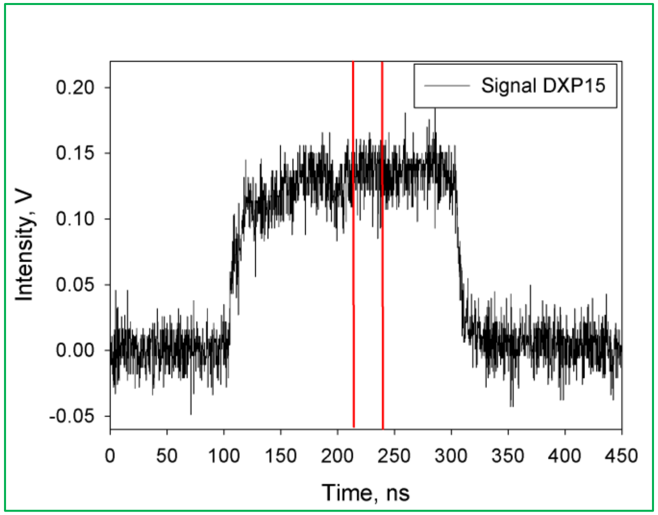


Average current scan over 21 minutes. The current stability is approximately 2% with respect to the average value of the current.

Interferometric measurements





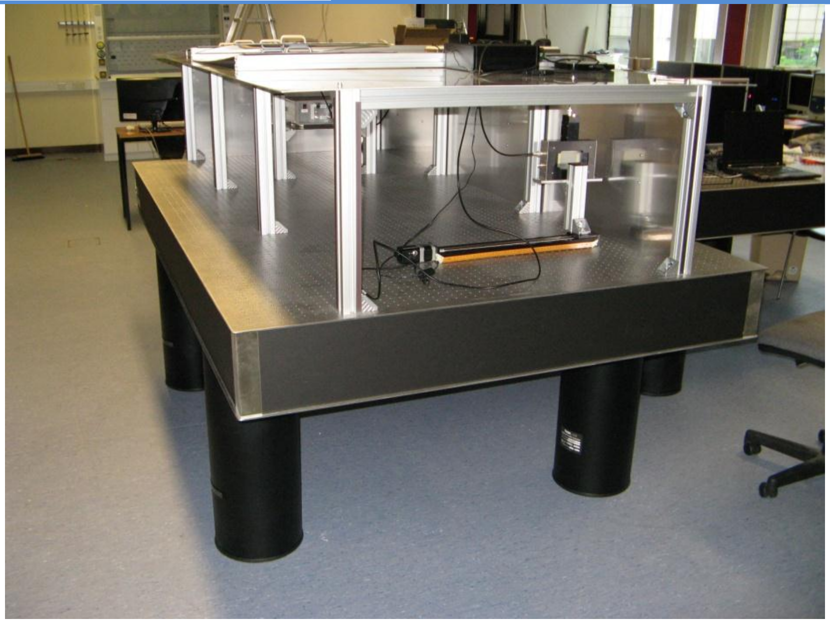


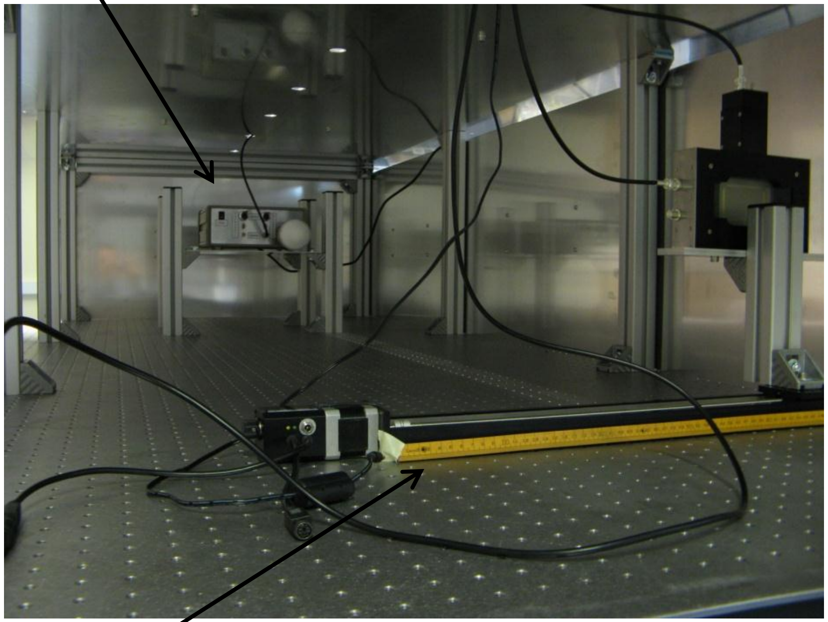
The interferometric scan is taken over the stage travelling range of 30mm.

In order to calculate a data point an average power over 25ns slice of the pulse is obtained.

A low frequency cut-off at 50 GHz.

Microwave lab at RHUL





Conclusions

- A theoretical model based on the Classical Diffraction Radiation Theory was developed.
- The CDR spatial distribution measurements were performed and compared with the theory.
- Bunch length variation issues at CTF3 were investigated.
- Interferometric measurements were performed utilizing the SBD detectors.

Problematic issues:

- the bunch length/shape variation along the pulse;
- the long term machine drift;
- an idealised theory along with the coherent backgrounds generated by the beam complicate the results interpretation;
- difficult to identify a high frequency cut-off of the SBD detectors.

Outlook

- usage of low frequency detectors to suppress the influence of a bunch shape variation;
- possible use of shot by shot measurements, grating spectrometer;
- microwave lab is being built at JAI Royal Holloway College.